

- ASGMT 2012 -  
LNG Supply Chain & Custody Transfer  
Measurement in the U.S.



# AGENDA

1. US NATURAL GAS OVERVIEW
2. US NATURAL GAS INFRASTRUCTURE
3. LNG SUPPLY CHAIN MEASUREMENT
4. APPENDIX

# SOME GAS HISTORY 1850-2006

- ◆ 500 BTU/CF Manufactured Coal Gas was being Utilized in Europe and especially UK in the early to mid-1800's
- ◆ Manufactured Coal Gas was being Utilized in Major US Cities by the Civil War as Numerous Municipal Gas Lighting and then Heavy Industrial Applications.
- ◆ Natural Gas Transmission arrived in NE in the early 1950's.
- ◆ Complete Appliance Conversion was Required because of the new 1000 BTU/CF Fuel.
- ◆ Propane Air was quickly identified as a peak shaving Fuel.
- ◆ LNG and NY/PA Midstream Gas Storage was Developed in Parallel.

# US GAS SUPPLY SUMMARY

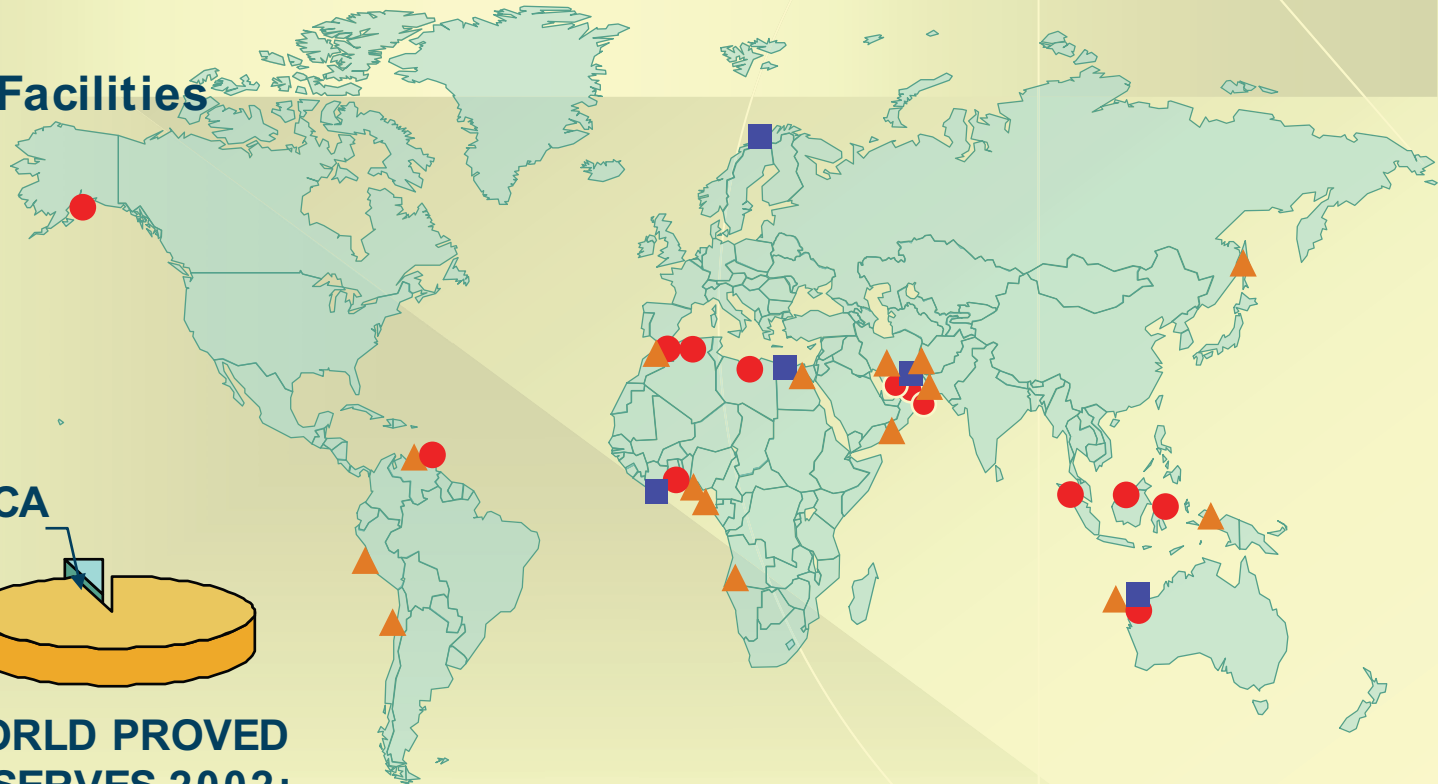
1. **23.5 TCF/Y Non-linear Use**
2. **20TCF is produced domestically**
3. **3 TCF Imported from Canada and declining.**
4. **.7TCF/Y imported LNG represents less than 2% of US use.**
5. **Approximately 100 LNG Facilities in US.**
6. **8 Marine Import Terminal in the US.**
7. **Approximately 100 BCF of LNG Storage in US.**
8. **37 LNG Facilities located in Northeast.**
9. **Approximately 3.5 TCF of Underground Storage in US.**
10. **Approximately 400 gas storage fields in US.**
11. **Gas costs per MMBTU: approximately \$2.75**



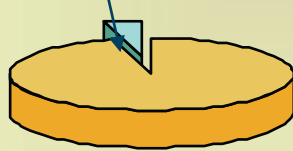
# US USES 24% OF ANNUAL WORLD SUPPLY, AND HAS 4% OF WORLD RESERVES

## Global LNG Supply Facilities

- Existing
- Under Construction
- ▲ Proposed



**NORTH AMERICA  
RESERVES  
4%**



**WORLD PROVED  
RESERVES 2002:  
6,270 TCF**

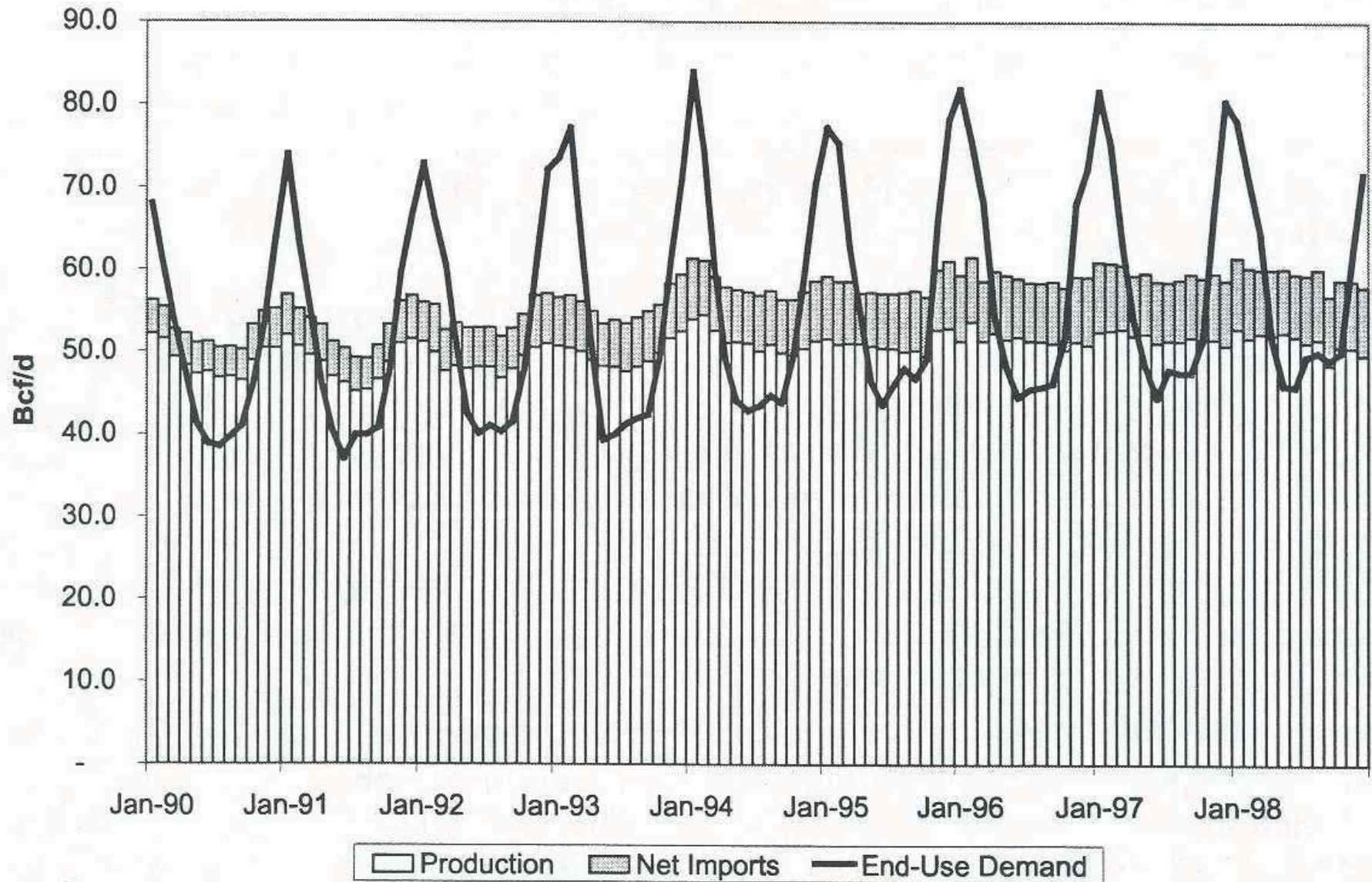
- LNG supply growing
- Multiple LNG supply proposals announced
- Long term LNG supply outlook robust

# SOME REGULATORY MILESTONES

- ◆ **Natural Gas Act 1938: First Federal Regulation in Gas Industry. Rates, Section 7 Permits Public Convenience, and Section 3 Permits for Import and Export.**
- ◆ **49 CFR 192: Minimum Safety Standards for Gas Distribution and Transmission established as Federal law in 1970.**
- ◆ **49CFR 193: Minimum Federal Safety Standards for LNG Established as Federal Law in 1978.**
- ◆ **FERC Order 636 Unbundling and Open Access in 1992.**
- ◆ **Energy Policy Act 2005.**

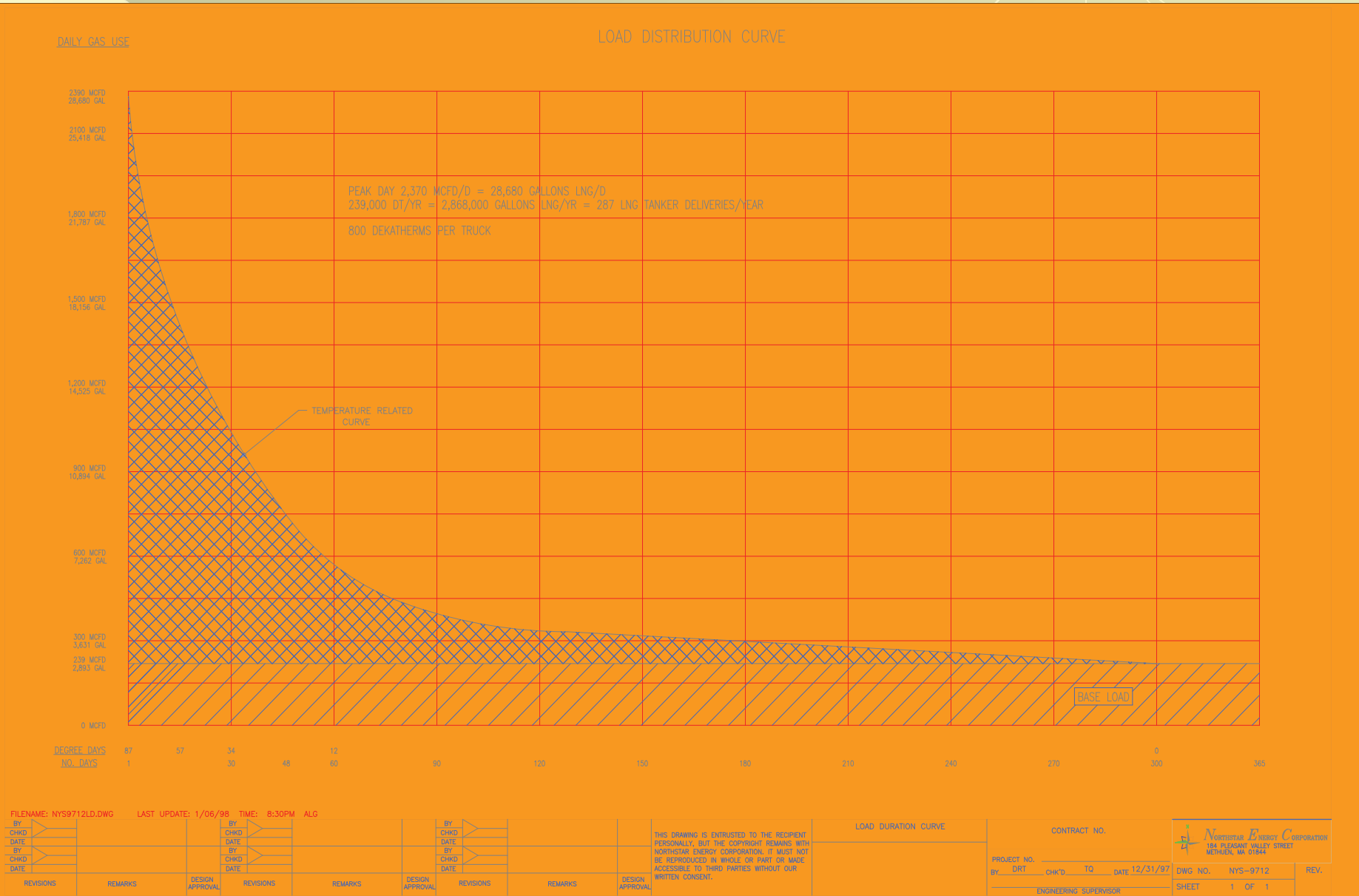


# US GAS SUPPLY AND DEMAND CURVES



# ANNUAL LOAD DURATION CURVE FOR CAPACITY PLANNING

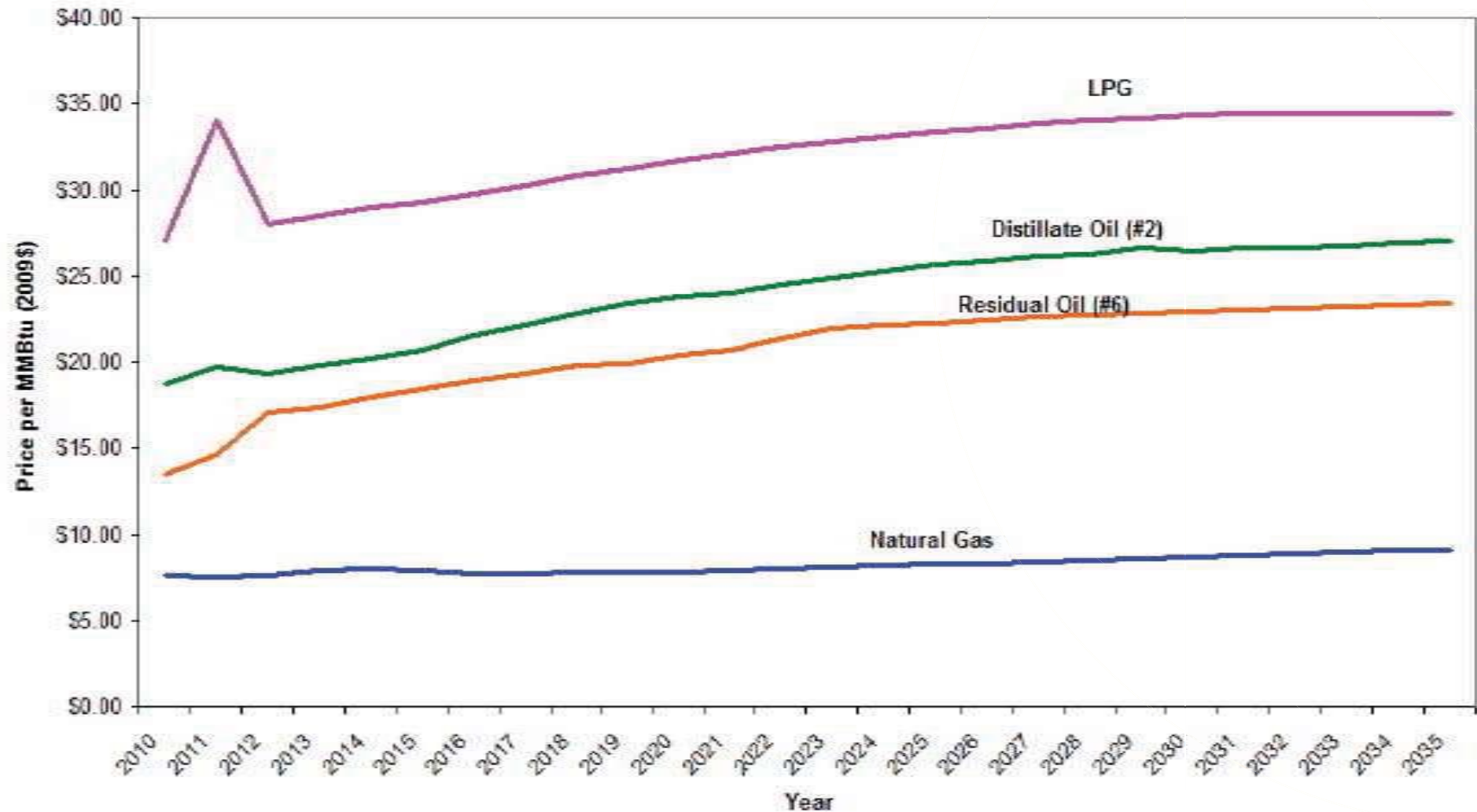
100,000 MCF PER DAY CAPACITY COSTS \$36-72MM PER YEAR.





# SUSTAINED NATURAL GAS PRICE ADVANTAGE IS EXPECTED FOR NEW ENGLAND

EIA Annual Energy Outlook - 2011  
Industrial Sector Commodity Price Forecast - New England



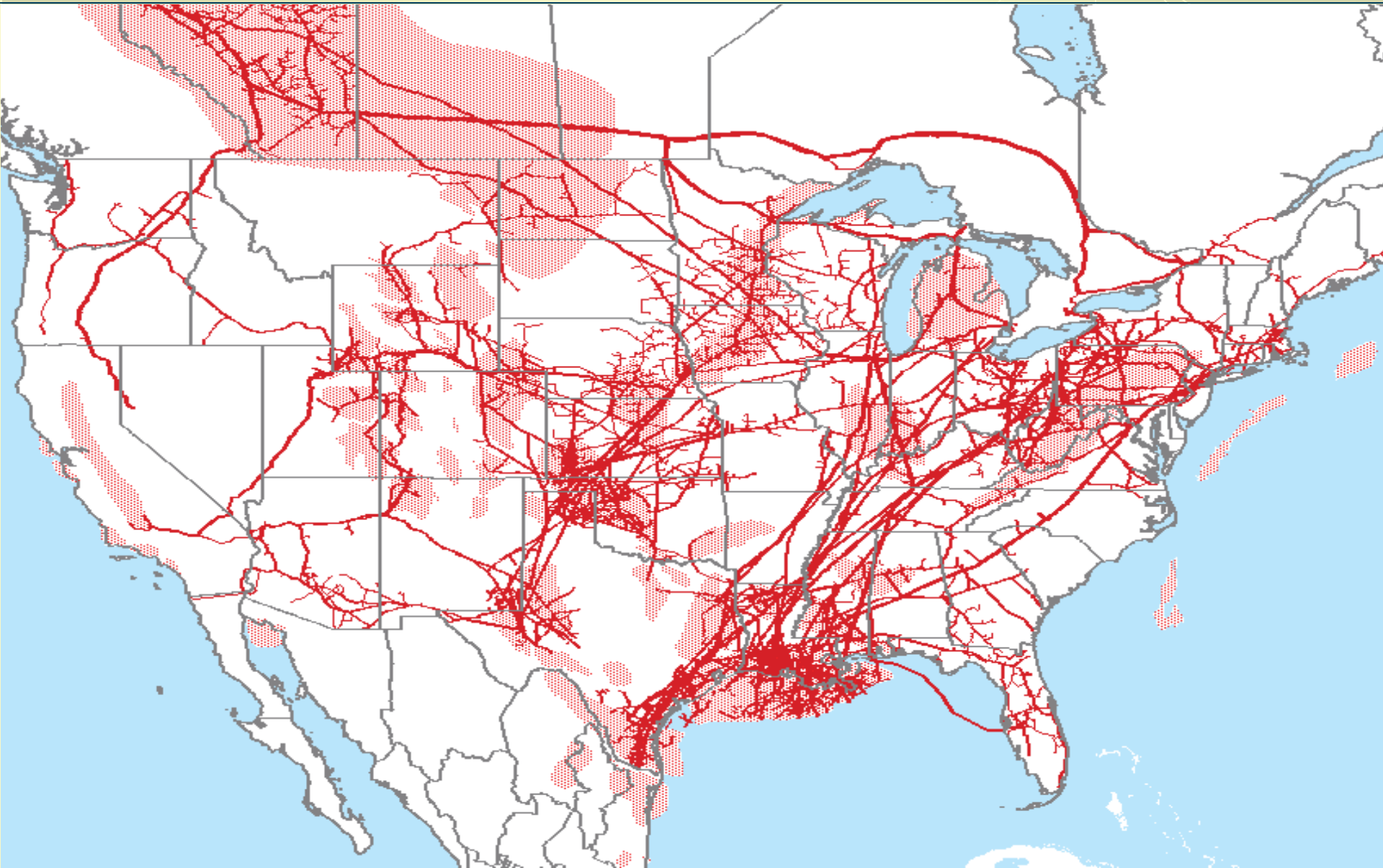
# MARKET ANALYSIS: COST IMPACT ON CRUDE OIL PRICE

Price Per Barrel Crude Oil	No. 2, Diesel, Gasoline Per MMbtu (approx.)
\$140	\$33.60
\$130	\$31.20
\$120	\$28.80
\$115	\$27.60
\$110	\$26.40
\$104	\$25.00
\$100	\$24.00
\$95	\$22.80
\$90	\$21.60
\$85	\$20.40
\$80	\$19.20
\$75	\$18.00
\$70	\$16.80
\$60	\$14.40
\$50	\$12.00
\$40	\$9.60
\$30	\$7.20

# AGENDA

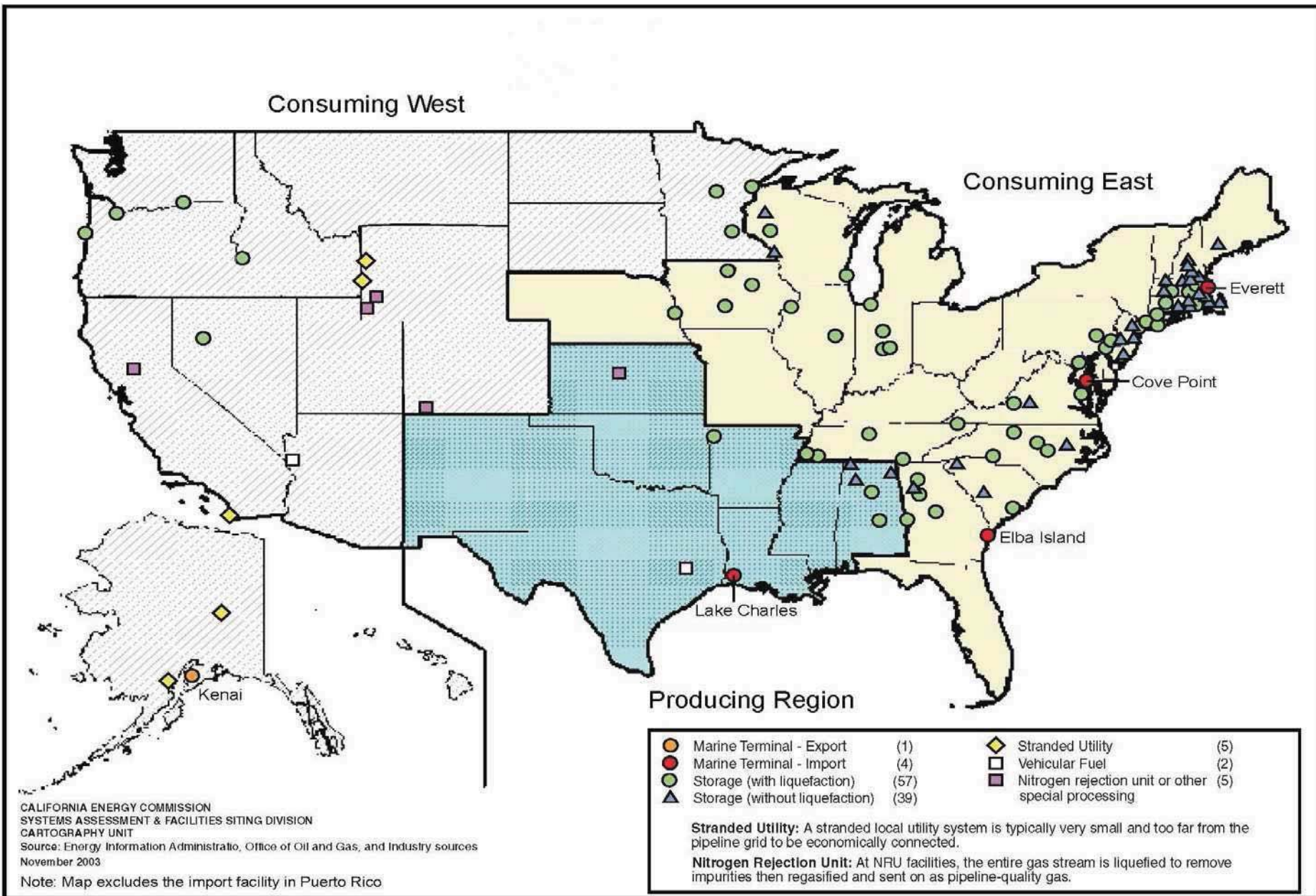
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# MAJOR US AND CANADIAN PIPELINES AND GAS PRODUCTION AREAS





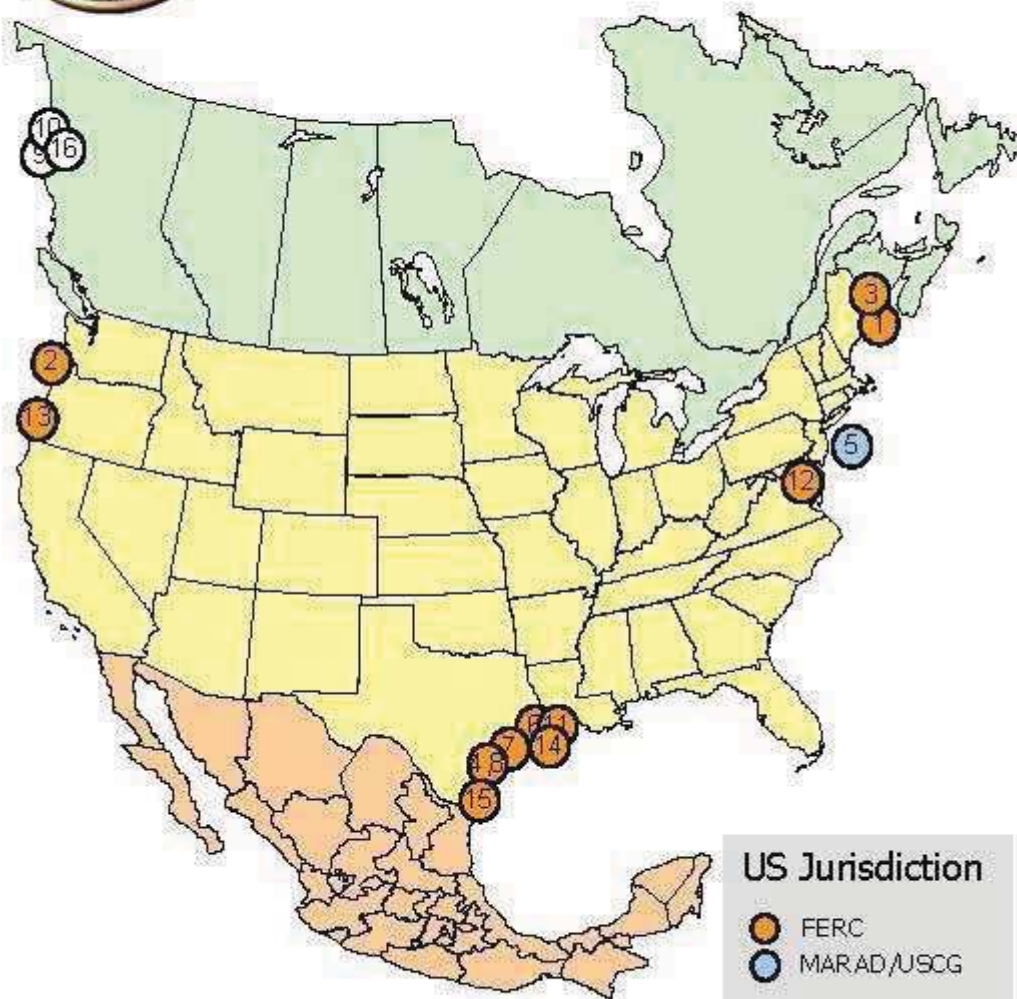
# US LNG FACILITIES





# North American LNG Import/Export Terminals

## *Proposed/Potential*



### Import Terminal

#### PROPOSED TO FERC

1. **Robbinston, ME:** 0.5 Bcfd (Kestrel Energy - Downeast LNG)
2. **Astoria, OR:** 1.5 Bcfd (Oregon LNG)
3. **Calais, ME:** 1.2 Bcfd (BP Consulting LLC)
4. **Corpus Christi, TX:** 0.4 Bcfd (Cheniere - Corpus Christi LNG)

#### PROPOSED TO MARAD/COAST GUARD

5. **Offshore New Jersey:** 2.4 Bcfd (Excalibur Energy - Liberty Natural)

### Export Terminal

#### PROPOSED TO FERC

6. **Sabine, LA:** 2.6 Bcfd (Cheniere/Sabine Pass LNG)
7. **Freeport, TX:** 1.8 Bcfd (Freeport LNG Dev/Freeport LNG Expansion/FLNG Liquefaction)
8. **Corpus Christi, TX:** 1.8 Bcfd (Cheniere - Corpus Christi LNG)

#### PROPOSED CANADIAN SITES IDENTIFIED BY PROJECT SPONSORS

9. **Kitimat, BC:** 0.7 Bcfd (Apache Canada Ltd.)
10. **Douglas Island, BC:** 0.25 Bcfd (BC LNG Export Cooperative)

#### POTENTIAL U.S. SITES IDENTIFIED BY PROJECT SPONSORS

11. **Lake Charles, LA:** 2.0 Bcfd (Southern Union & BG LNG)
12. **Cove Point, MD:** 1.0 Bcfd (Dominion - Cove Point LNG)
13. **Coos Bay, OR:** 1.2 Bcfd (Jordan Cove Energy Project)
14. **Hackberry, LA:** 1.7 Bcfd (Sempra - Cameron LNG)
15. **Brownsville, TX:** 2.8 Bcfd (Gulf Coast LNG Export)

#### POTENTIAL CANADIAN SITES IDENTIFIED BY PROJECT SPONSORS

16. **Prince Rupert Island, BC:** 1.0 Bcfd (Shell Canada)

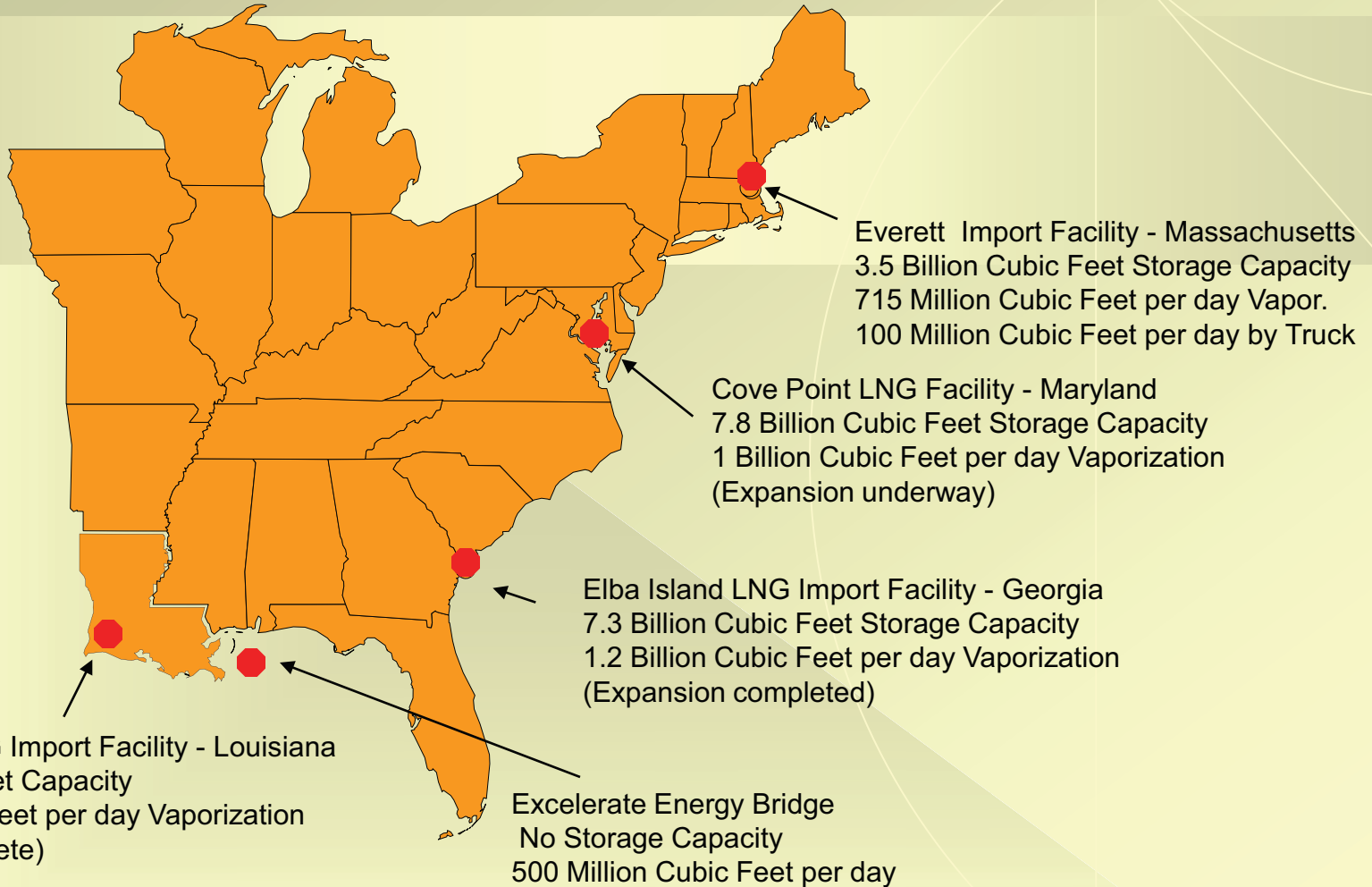
As of February 28, 2012

*Office of Energy Projects*



# US MARINE IMPORT LNG FACILITIES

## IMPORTED 650 BCF IN 2005



## 3.5 TCF WORKING GAS US GEOLOGICAL GAS STORAGE



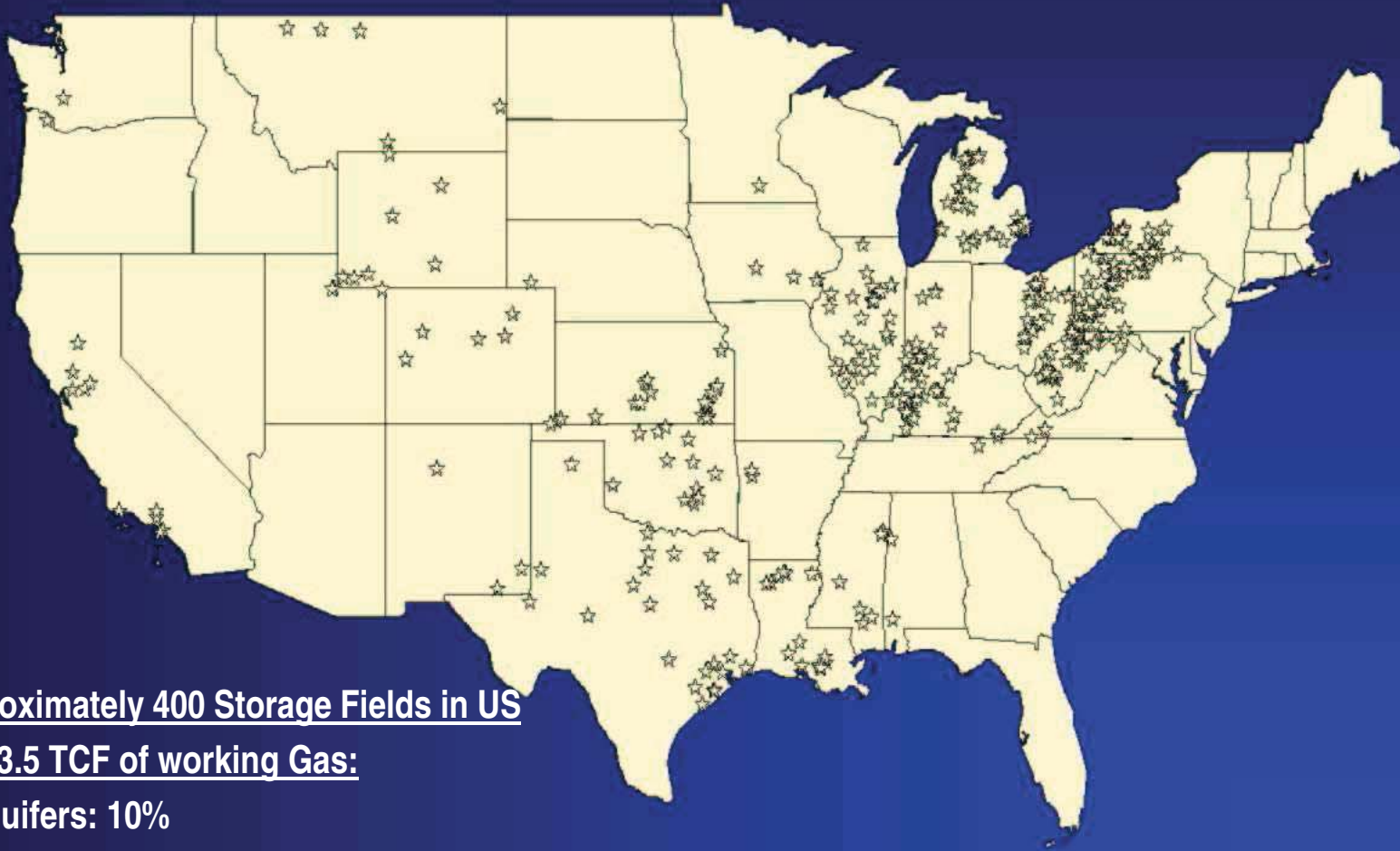
### GAS Storage Field

20 BCF Working Gas/20 BCF Pad Gas:

Header, Production Wells, Observation Wells, Dehydration, SCADA,  
Compression, Flow Control, Metering and Regulation



# US GAS STORAGE FIELDS



1. Approximately 400 Storage Fields in US  
with 3.5 TCF of working Gas:

1. Aquifers: 10%
2. Depleted Gas/Oil Reservoir 86%
3. Cavern within Salt Dome 4%

2. Supply Source: Interstate or Intrastate Pipelines

# AGENDA

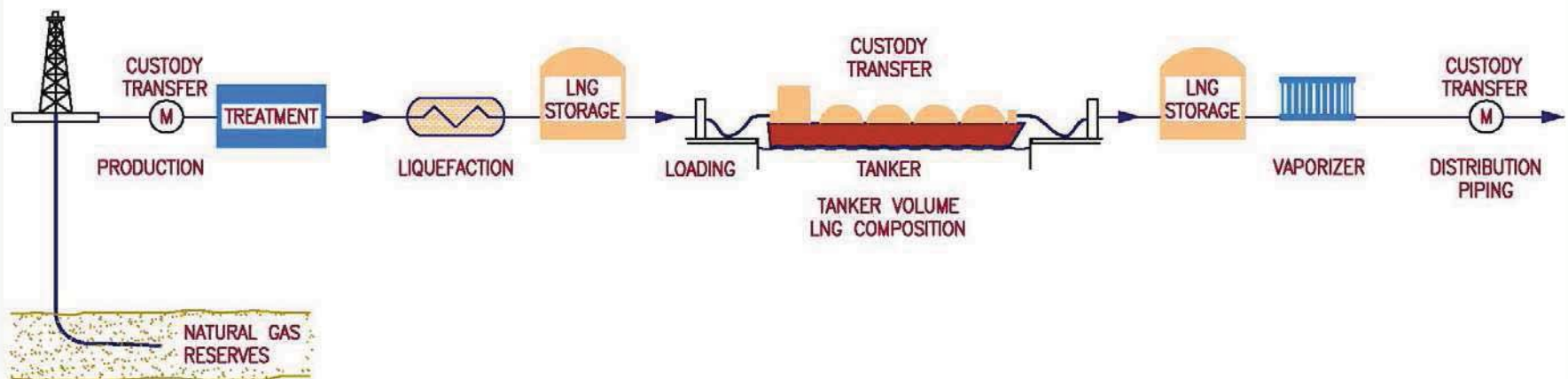
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# 10 HELPFUL LNG RULES OF THUMB



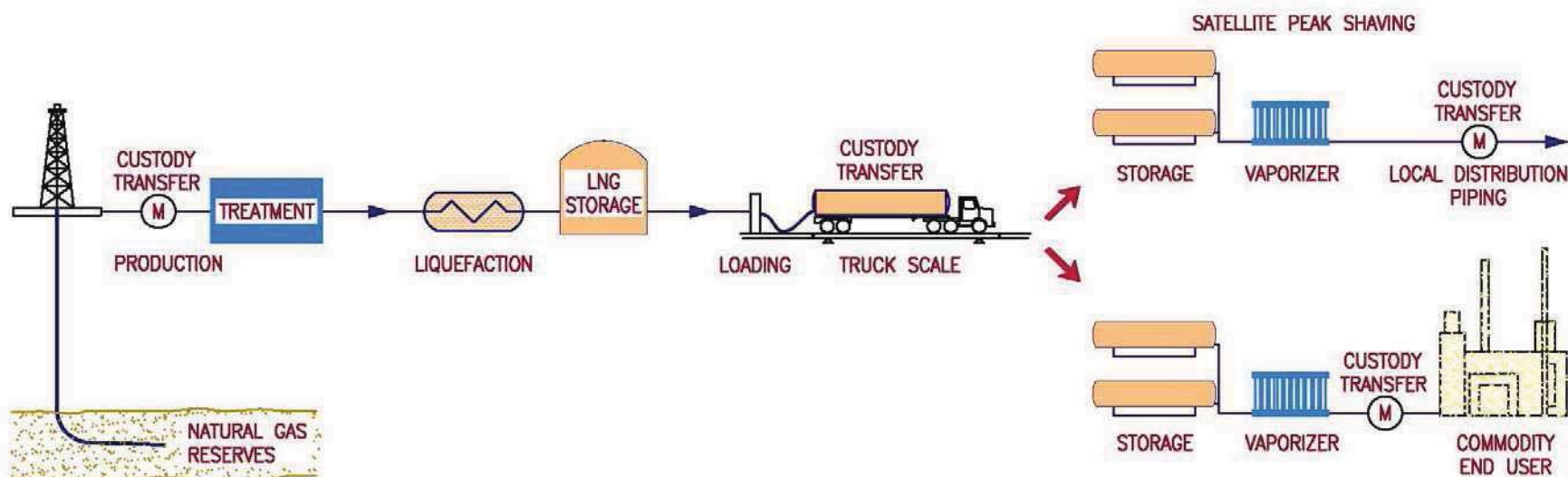
1. Detection:	Odorless, Colorless & Nontoxic
2. Boiling Point at Atm Press.:	-260°F
3. Expansion Ratio from Liquid to Vapor:	618 to 1
4. Volume of LNG per MSCF:	12.1 Gallons
5. Volume of Gas in 10,000 Gallon LNG Trailer:	833 MSCF
6. Flow of LNG to Vaporize 500 MSCFH:	100 GPM
7. Specific Gravity of Liquid (Water = 1.0):	0.46
8. Specific Gravity of Vapor at -260°F (Air = 1.0):	1.43
9. Latent Heat of Vaporization at Atm Press.:	219 BTU's / lbs.
10. Specific Heat of Vapor at Atm Press.:	0.52 BTU's / lbs.-°F

# INTERNATIONAL LNG SUPPLY CHAIN





# DOMESTIC LNG SUPPLY CHAIN



# **TYPES OF LNG MEASUREMENT TRANSACTIONS**

## **CUSTODY TRANSFER:**

- 1. LNG Supply at Marine Terminal via Ship**
- 2. LNG Supply via Truck to a Peak Shaving Plant or End User Site**
- 3. Regasified LNG to Power Plant, End User, or Interstate Pipeline**

**In all cases listed above, gas composition is required to determine energy content, and is measured according to either: Volume, Weight, or Cubic Footage**

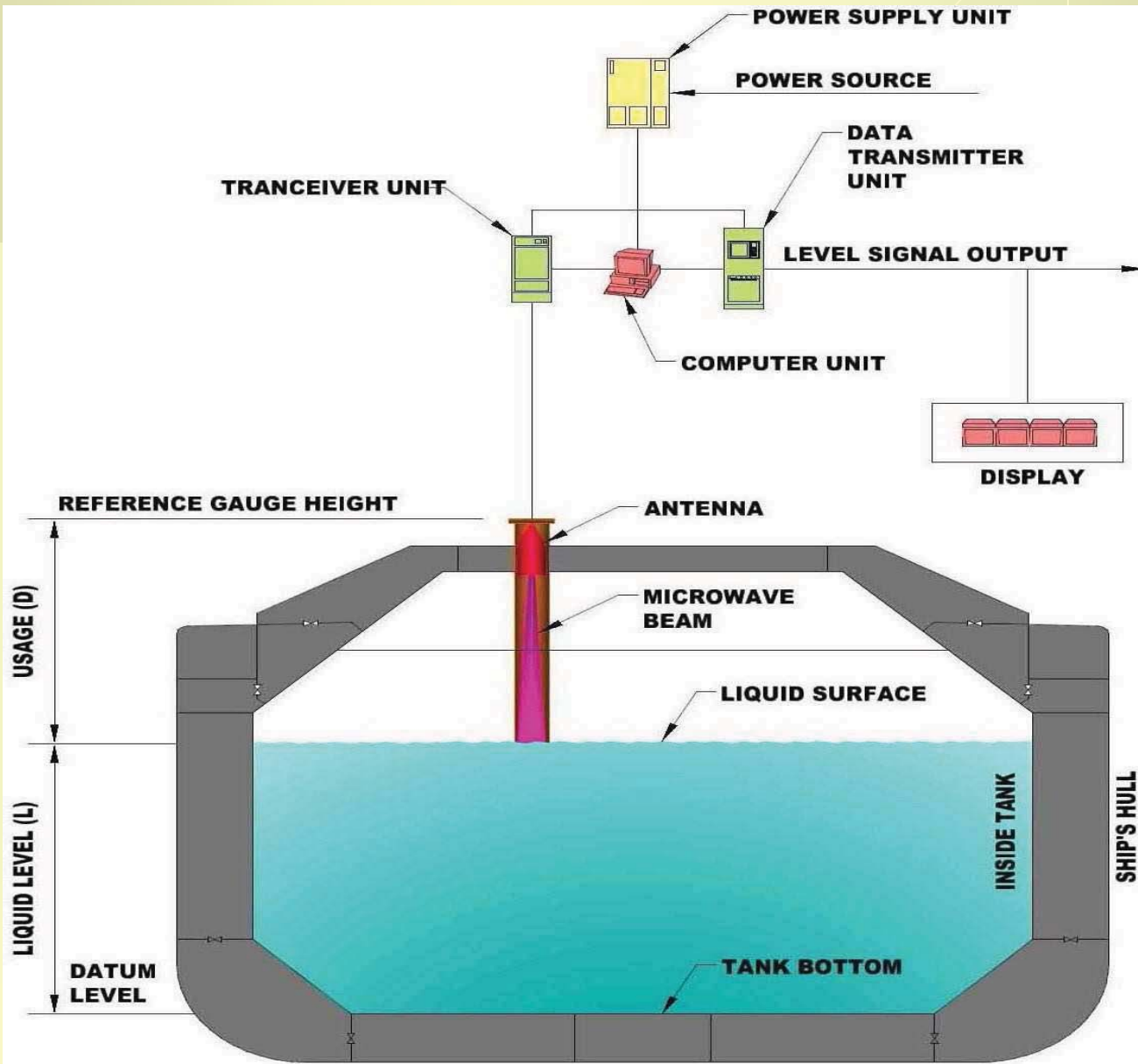
## **PROCESS CONTROL:**

- 1. Generally Conducted in Liquid Stage.**

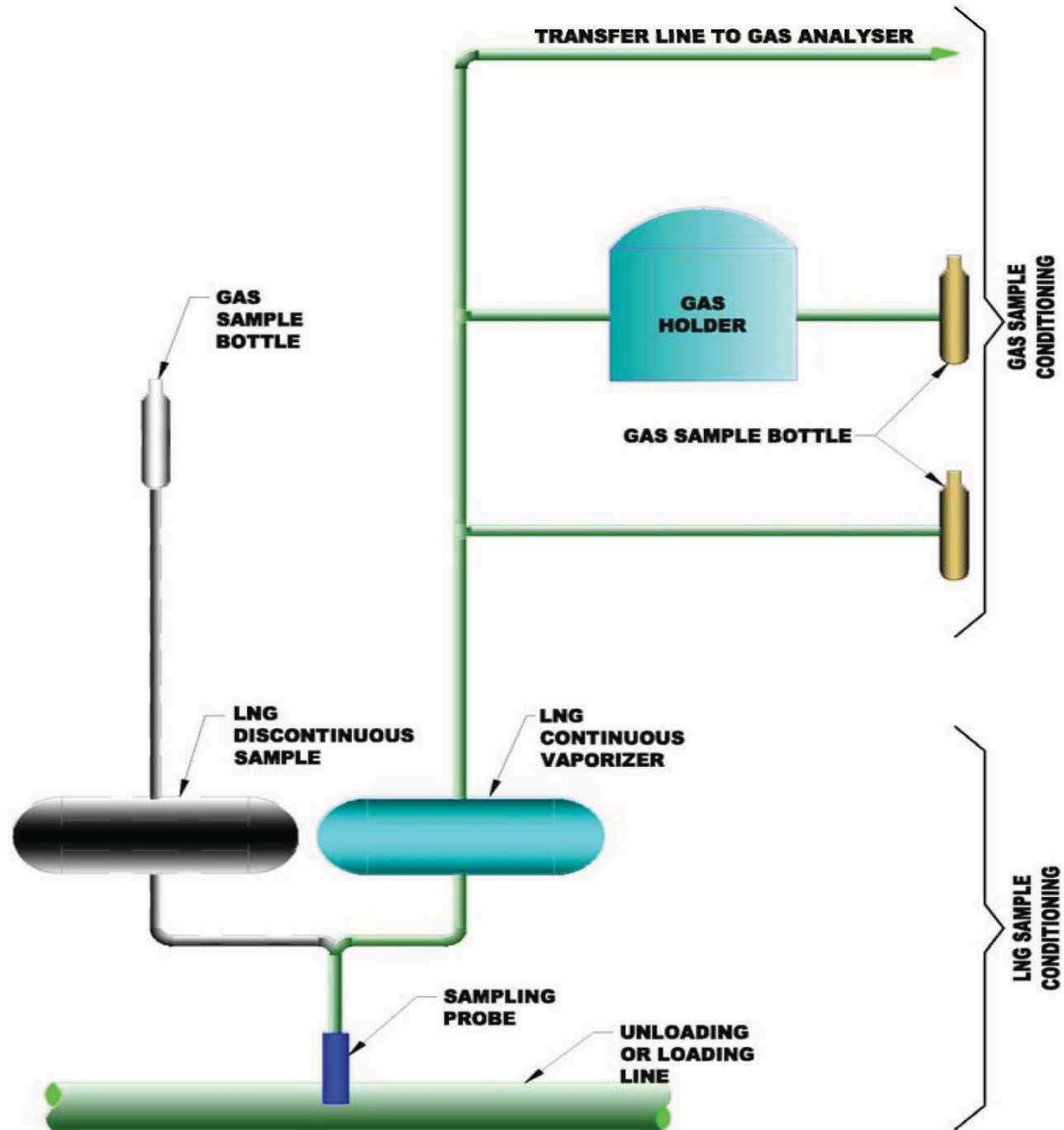
# LNG SUPPLY AT MARINE TERMINAL VIA SHIP



# - MEASUREMENT AT LNG TERMINAL- RADAR (MICROWAVE) TYPE LEVEL GAUGE



# LNG SAMPLING CHAINS

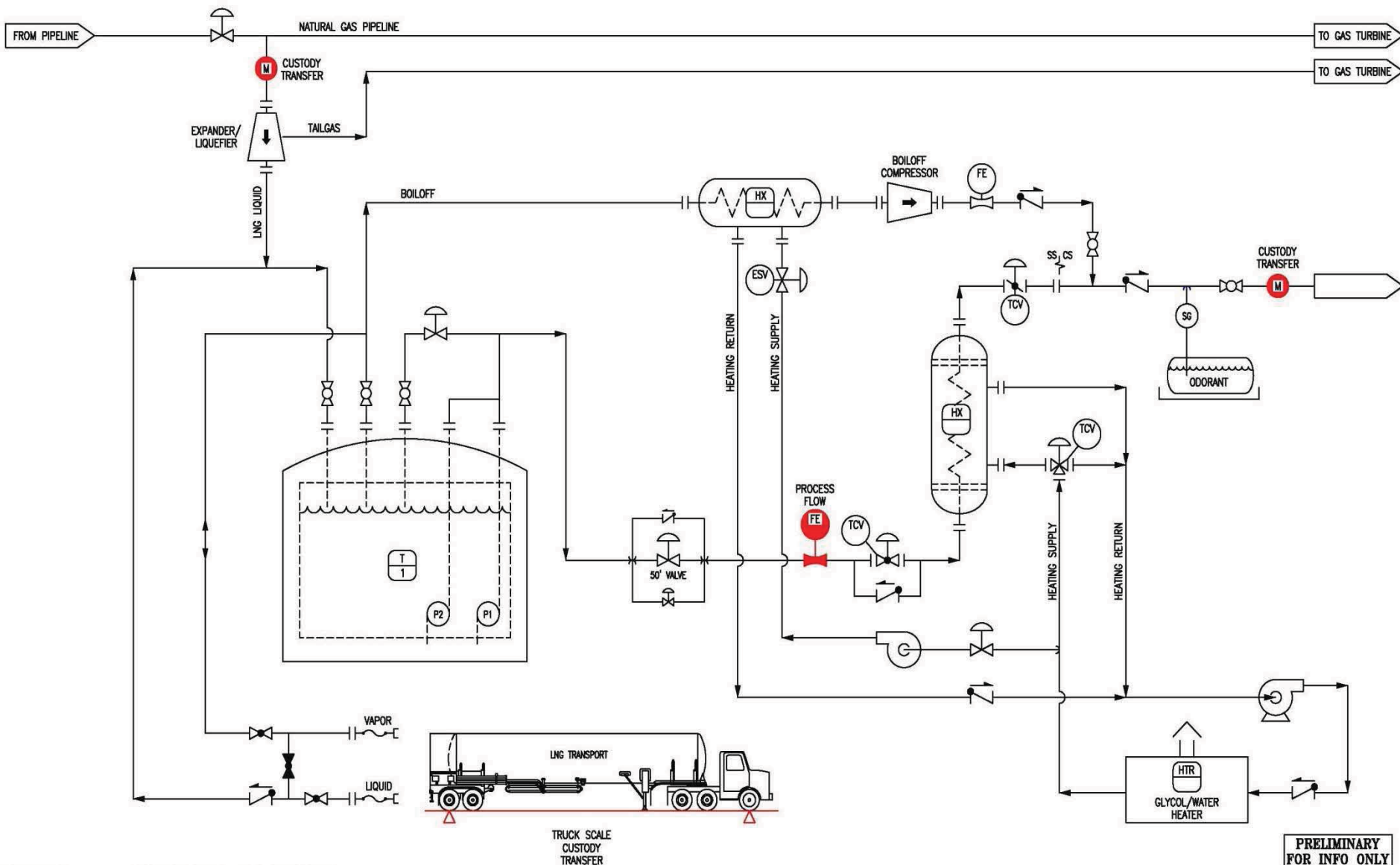


# LNG SUPPLY VIA TRUCK TO PEAK SHAVING PLANT OR END USER





# REGASIFIED LNG TO POWER PLANT, END USER, OR INTERSTATE PIPELINE



PRELIMINARY  
FOR INFO ONLY

FILENAME: FNAME

LAST UPDATE: UPDATE TIME: UPDATE UPBY

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TYPICAL  
PROCESS FLOW DIAGRAM

PROJECT NO. \_\_\_\_\_

BY: \_\_\_\_\_ DATE: \_\_\_\_\_

CHK'D: \_\_\_\_\_ DATE: \_\_\_\_\_

PROJECT MANAGER

DWG NO. 1B1

SCALE NONE

REV. A

# MEASUREMENT AFTER REGASIFICATION





# LNG TANKER TRUCK ON WEIGH SCALE



# AGENDA

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# APPENDIX LNG FACILITIES

## TECHNICAL FACTS:

- History
- Design
- Siting
- Codes and Standards
- Equipment Selection

# HISTORY OF LNG

- **1941: First large-scale LNG liquefaction peak-shaving facility built by East Ohio Gas Company in Cleveland.**
- **1944: Catastrophic LNG tank failure at Cleveland facility kills 128 people and sets back LNG industry in USA.**
- **1954: First ship transport of LNG from Louisiana to Canvey Island (UK) where the first LNG import terminal was established by British Gas.**
- **1964: First large-scale LNG trade began when British Gas began importing by ship from Algeria.**
- **Mid-1960's to Mid-1970's: Rebirth of peak-shaving LNG industry in the USA due to supply shortages during peak demand periods.**
- **1980's: Deregulation of the gas industry in the USA increases LNG interest.**
- **Present: Predicted shortage of domestic gas supplies increases LNG interest.**



# HUB & SPOKE DISTRIBUTION OF LNG



Northstar LNG  
Facilities maximize  
utilization of existing  
large volume storage  
facilities.



# **CODES & STANDARDS: LNG FACILITIES**

- **US DOT 49 CFR Part 193: Liquefied Natural Gas Facilities - Federal Safety Standards**
- **NFPA 59A: Standard for the Production, Storage & Handling of Liquefied Natural Gas (LNG)**
- **NFPA 59A - Chapter 10: Alternate Requirements for Stationary Applications Using ASME Containers**
- **NFPA 59A- Paragraph 2-3.4: Temporary Use of LNG Portable Equipment**



# US DOT 49 CFR PART 193

LNG facilities used in the transportation of gas into pipelines or distribution systems regulated by 49 CFR Part 192 are subject to regulation by 49 CFR Part 193. There are approximately 95 LNG facilities in the USA, which fall under the jurisdiction of 49 CFR Part 193.

## I. FERC Regulated Facilities

A. LNG Facilities Supplying Interstate Pipelines

B. LNG Marine Terminals

## II. DOT Regulated Facilities

A. LNG Facilities Supplying Intrastate Pipelines or Distribution Systems

# THREE MAJOR TYPES OF LNG FACILITIES

## 1. Marine Terminals (Import or Export)

- Ship Loading or Unloading
- On-Site Storage
- Liquefaction or Vaporization
- Truck Loading



## 2. Peak-Shaving

- Liquefaction or Truck Unloading
- On-Site Storage
- Vaporization
- Truck Loading



## 3. Base-Load

- Liquefaction or Truck Unloading
- On-Site Storage
- Vaporization
- Truck Loading





# OTHER TYPES OF LNG FACILITIES

## 1. Vehicular Fueling

- Truck Unloading or Liquefaction
- On-Site Storage
- Vehicle Fueling



## 2. Stranded Gas Reserves

- Liquefaction
- On-Site Storage
- Truck Loading



## 3. Land Fill Gas

- Liquefaction
- On-Site Storage
- Truck Loading





# TWO MAIN TYPES OF LNG STORAGE TANKS

## 1. Field Erected (API-620 Appendix Q):

- 1,000,000 to 42,000,000 Gallons (3,800 to 160,000 Cubic Meters)
- 0.5 to 2 psig Design Pressure
- Pre-Stressed Concrete
- Single Containment (9% Nickel Steel Inner Tank & Carbon Steel Outer Tank)
- Full Containment (9% Nickel Steel Inner Tank & Concrete Outer Tank)
- External or Internal Sendout Pumps



## 2. Shop Fabricated (ASME):

- 30,000 to 70,000 Gallons (113.5 to 265 Cubic Meters)
- 70 to 250 psig Design Pressure
- 9% Nickel Steel Inner Tank & Carbon Steel Outer Tank
- Horizontal or Vertical Configuration
- Above Ground or Buried
- Differential Pressure Sendout or External Sendout Pumps



# TYPES OF LIQUEFACTION SYSTEMS

- ◆ **Natural Gas Expander**
- ◆ **Cascade Refrigeration**
- ◆ **Mixed Refrigerant**
- ◆ **Nitrogen Recycle**



# TYPES OF VAPORIZERS

- ◆ Direct Fired
- ◆ Indirect Fired Water Bath
- ◆ Indirect Fired Submerged Combustion
- ◆ Ambient Heat
- ◆ Remote Heated Shell and Tube
- ◆ Remote Heated Falling Film
- ◆ Open Rack Seawater



# DEVELOPMENT STEPS

1. Preparation of concise conceptual baseline foundation.
  - Determine need, design baseline, jurisdictions, cost/schedule, economics.
  - Include all cost centers: Land, Afudc, Overheads, Grossup, Utilities.
  - Project milestone: Go/No Go
2. Establish site and project control.
3. Preparation of filings, final design, and engineering.
4. Open seasons or revenue stream commitments.
5. Establish Supply.
6. Final design and EPC contracts.
7. Adjudicate permits.
8. Set up operating company.
9. Procurement, construction, commissioning, and future O&M.

# **SITING ISSUES: 49 CFR Part 193 FIXED FACILITIES SUPPLYING 49 CFR PART 192 CUSTOMERS)**

**Design, Construction, and Operations per 49 CFR Part 193 and by experienced, qualified and fit for duty people. The project must be implemented with 1.) Construction, 2.) Operating, 3.) Maintenance, 4.) Security, 5.) Fire, & 6.) Emergency Plans.**

**The design must also consider the following siting issues.**

- ◆ **THERMAL RADIATION**
- ◆ **VAPOR DISPERSION**
- ◆ **SEISMIC**
- ◆ **FLOODING**
- ◆ **SOIL**
- ◆ **WIND**
- ◆ **SEVERE WEATHER**
- ◆ **ADJACENT ACTIVITY**
- ◆ **SEPARATION**
- ◆ **AIRPORTS**



# THERMAL RADIATION PROTECTION

Provisions shall be made to minimize the possibility of the damaging effects of fire reaching beyond a property line that can be built upon and that would result in a distinct hazard.

In calculating exclusion distances, the wind speed, ambient temperature and relative humidity that produce the maximum exclusion distances shall be used except for those values that occur less than 5% of the time based on recorded data for the area.

**1,600 Btu/hr/ft<sup>2</sup>** at a property line that can be built upon for ignition of a design spill.

**1,600 Btu/hr/ft<sup>2</sup>** at the nearest point located outside the owner's property line that, at the time of plant siting, is used for outdoor assembly by groups of 50 or more persons for a fire over an impounding area.

**3,000 Btu/hr/ft<sup>2</sup>** at the nearest point of the building or structure outside the owner's property line that is in existence at the time of plant siting and used for occupancies classified by NFPA 101®, Life Safety Code®, as assembly, educational, health care, detention and correction or residential for a fire over an impounding area.

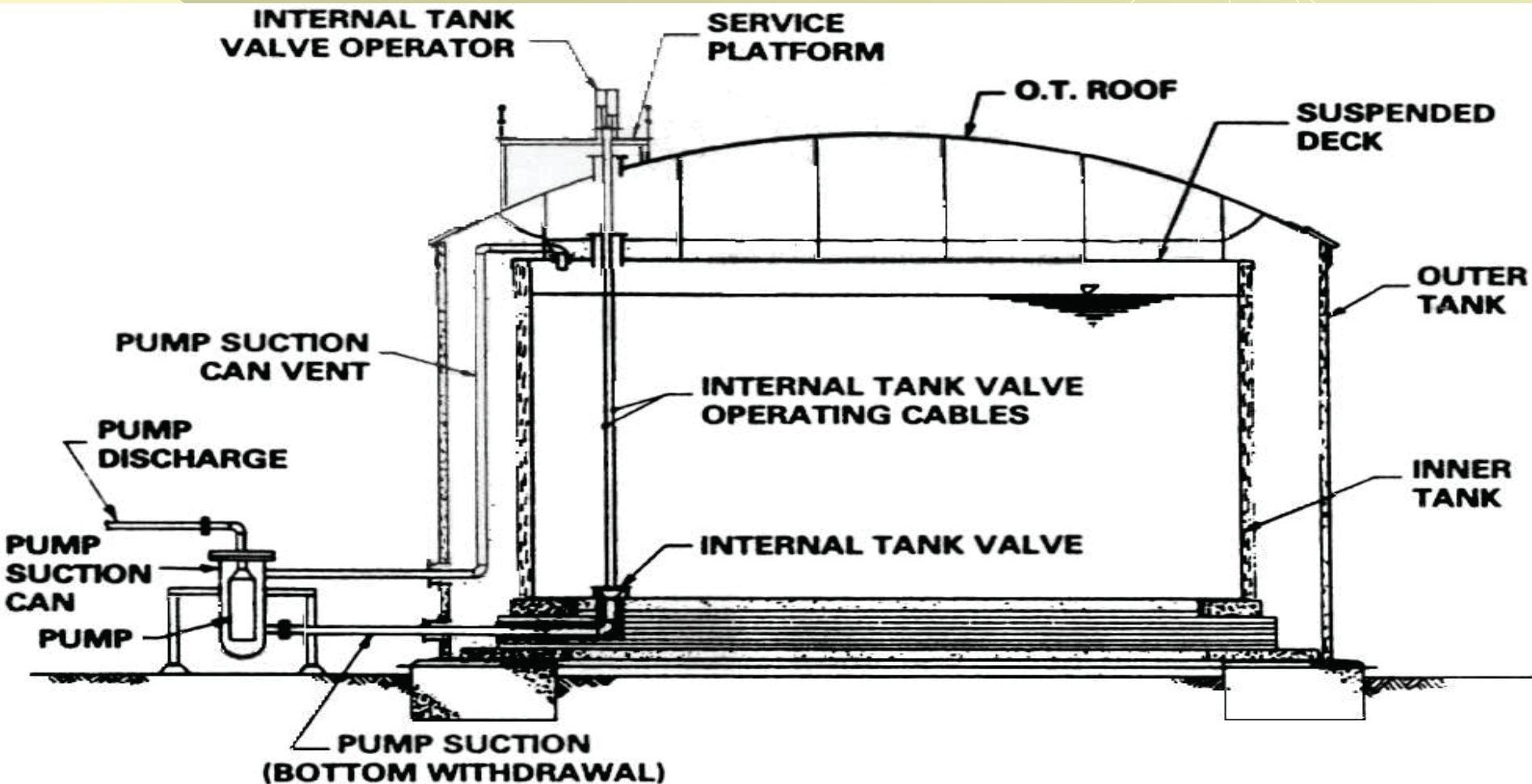
**10,000 Btu/hr/ft<sup>2</sup>** at a property line that can be built upon for a fire over an impounding area.

# VAPOR DISPERSION PROTECTION

**Provisions shall be made to minimize the possibility of a flammable mixture of vapors from a design spill, as appropriate, reaching a property line that can be built upon and that would result in a distinct hazard.**

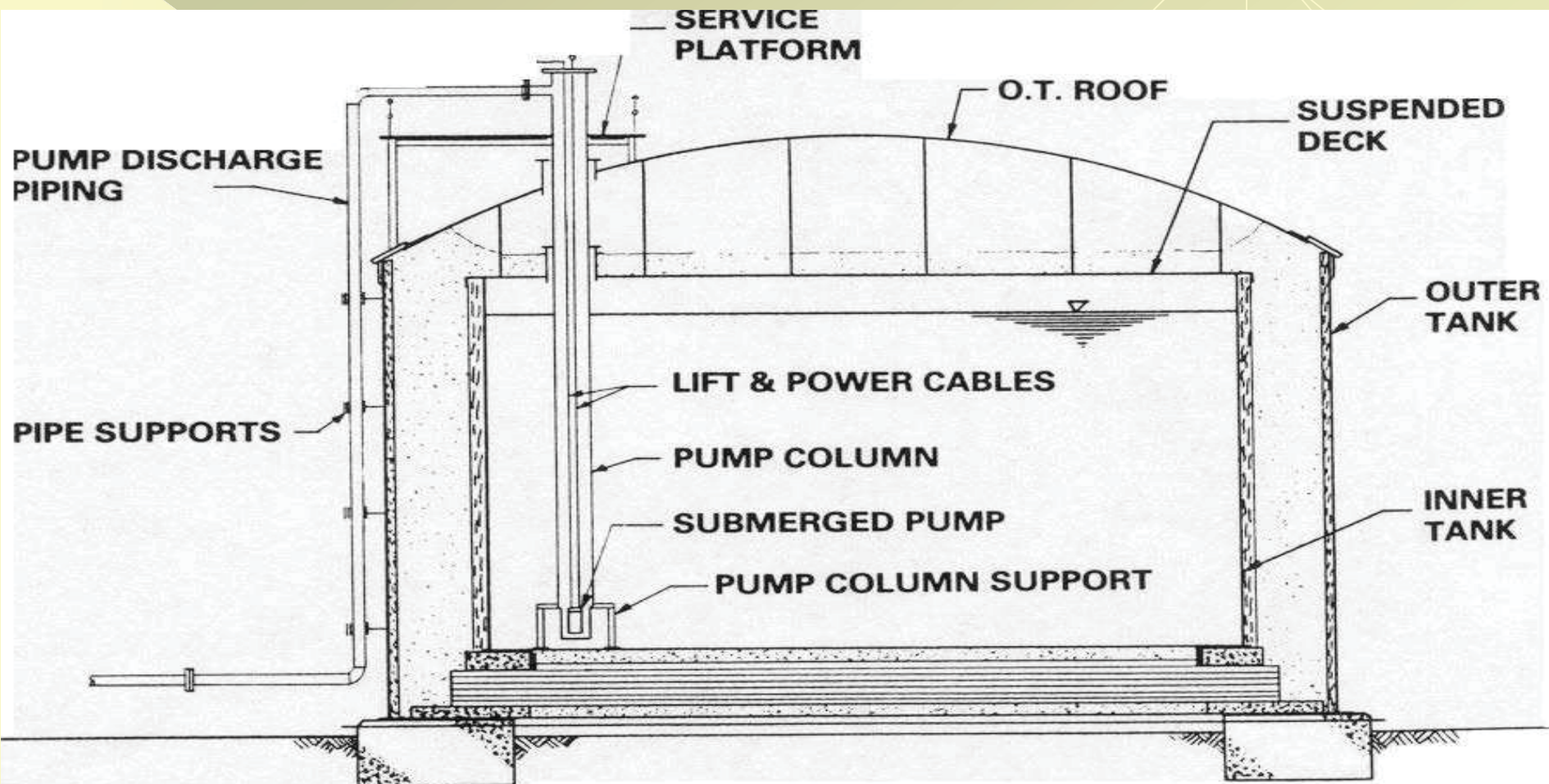
- Flammable mixture dispersion distances shall be calculated in accordance with the model described in Gas Research Institute report GRI 0242, “LNG Vapor Dispersion Prediction with the DEGADIS Dense Gas Dispersion Model.”**
- The effects of provisions for detaining vapor or otherwise mitigating flammable vapor hazards (e.g., impounding surface insulation, water curtains, or other methods) shall be permitted to be considered in the calculation where acceptable to the authority having jurisdiction.**

# DESIGN SPILL: BOTTOM PENETRATION TANKS WITH INTERNAL SHUTOFF VALVES



**Design Spill:** A spill through an assumed opening at, and equal in area to, that penetration below the liquid level resulting in the largest flow from an initially full tank for one (1) hour.

# DESIGN SPILL: TANKS WITH PENETRATIONS ABOVE THE LIQUID LEVEL



**Design Spill:** The largest flow from any single line that could be pumped into the impounding area with the container withdrawal pump(s) delivering the full rated capacity for ten (10) minutes.



# PEAK SHAVING ECONOMIC JUSTIFICATION ESTABLISHING PRICING FOR PEAK SERVICE



## CARRYING COST VERSUS CAPACITY

- I. Annual Carrying Cost = Annual Mortgage + O&M + Margin
- II. Capacity Cost for Pipeline Capacity is generally is priced \$/Dec/D:  
\$.5 - \$2.50 Nationwide results in \$18 Million -\$100 Million Per Year  
PER 100,000 Dec/D of Long haul Pipeline Capacity



# INTERSTATE PROJECT OVERVIEW

- ◆ **Feasibility Analysis**
- ◆ **Finance/Procurement/Lease/Purchase**
- ◆ **Pre-Filing Application**
- ◆ **Open Season**
- ◆ **Submission of Resource Reports**
- ◆ **Public Hearings**
- ◆ **Environmental Impact**
- ◆ **Receive FERC Permit and Conditions**
- ◆ **Balance of Final Design and Local Permits**
- ◆ **Pre-manufacturing**
- ◆ **Installation**
- ◆ **Project Documentation**
- ◆ **Procedures & Plans**
- ◆ **Commission & Train**



# INTERSTATE APPROVALS

- ◆ **STATE ENERGY SITING BOARDS**
- ◆ **STATE PUBLIC UTILITY COMMISSION**
- ◆ **STATE DEVELOPMENT LAWS**
- ◆ **FLAMMABLE STORAGE PERMITS**
- ◆ **CONSERVATION COMMISSIONS**
- ◆ **COASTAL ZONE MANAGEMENT**
- ◆ **LOCAL ZONING & PERMITS**
- ◆ **FIRE AUTHORITIES**
- ◆ **EPA DISCHARGE & AIR**
- ◆ **EPA EMERGENCY RESPONSE**